Test Plan for the Demonstration and Characterization of IP-Based Communications with the UoSAT-12 Spacecraft

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1 Introduction and Scope

The goal of the OMNI project is to help space missions to reduce development and operating costs by adopting widely supported Internet protocols (IP) and applications. Space communications protocols have evolved over the years in a relatively focused community of space users supported by a niche group of technology companies. The use of IP communications protocols has significant potential to save development and implementation cost by using inexpensive COTS products for flight system development and ground system development and implementation. IP-based technology has been widely accepted by the world as a standard for communications. IP-based network protocols will continue to evolve cost free to the user through industry support. This evolution will provide performance enhancements, new features, and inexpensive COTS product improvements.

This plan establishes the OMNI Project's approach to perform experimentation with and demonstration of core elements of Internet Protocol (IP) functions and capability in space communications architectures. This test plan documents the overall test flow and resources required in order to satisfactorily accomplish the test objectives.

The OMNI testing will be scheduled in three phases. Each phase will build upon the success and information gathered in the previous phase. Test Objectives not accomplished in one phase may be rolled into the test planning for the following phase. Test procedures will be developed separately for each phase, taking advantage of lessons learned.

2 Test Objectives

The goal of this test plan is to provide a means of validating the IP-in-space concept using standards established for Internet Protocols and IP-based transport protocols as defined by the Internet Engineering Task Force (IETF) in Requests for Comment (RFC). The demonstration of a minimum set of capabilities is viewed by the OMNI project as critical milestone in establishing that IP can be applied to a mission design as a low risk means of achieving cost savings.

The primary objective of the planned test activities is to collect data that will be used to evaluate the applicability of Internet protocols, IP-based transport protocols, and IP-based applications in space communications and operations processes. Parameterized performance metrics will be used to evaluate the collected data.

This test will include IP-based:

1) Uplink (command) and downlink (telemetry) capabilities.
2) Both connection-oriented transport protocols (e.g., TCP) and connectionless protocols (e.g., UDP).
3) The use of standard network applications such as file transfer (e.g., FTP), and time distribution (e.g., NTP).

The objectives of the test activities are:

1) Establish baseline performance characteristics
2) Perform parametric measurements
3) Extend our understanding of the impact of parameters related to IP that impact performance issues.

3 Applicable Documents

3.1 Request For Comment (RFC) Documents

	RFC #	Document Title
1	2400	INTERNET OFFICIAL PROTOCOL STANDARDS, Postel J., Reynolds J., 1998/09/24
2	791 S	Internet Protocol, Postel J., 1981/09/01
3	793 S	Transmission Control Protocol, Postel J., 1981/09/01 (85pp)
4	768 S	User Datagram Protocol, Postel J., 1980/08/28
5	1123 S	Requirements for Internet hosts - application and support, Braden R., 1989/10/01
6	1122 S	Requirements for Internet hosts - communication layers, Braden R., 1989/10/01
7	1700 S	ASSIGNED NUMBERS, Postel J., Reynolds J., 1994/10/20
8	959 S	File Transfer Protocol, Postel J., Reynolds J., 1985/10/01 (69pp)
9	958	Network Time Protocol NTP, Mills D., 1985/09/01
10	1825 -PS	Security Architecture for the Internet Protocol, Atkinson R., 1995/08/09
11	821 S	Simple Mail Transfer Protocol, Postel J., 1982/08/01

4 Organizational Relationships and Roles

The successful execution of this test plan will require the participation of three key organizations. The test program is managed and directed by NASA/GSFC with support from a number of engineering organizations. Surrey Satellite Technology Ltd. (SSTL) manages and operates the UoSAT-12 spacecraft and ground terminal facilities in the UK. VyTek, LLC will provide flight software support. An organizational chart is shown in Figure 1.

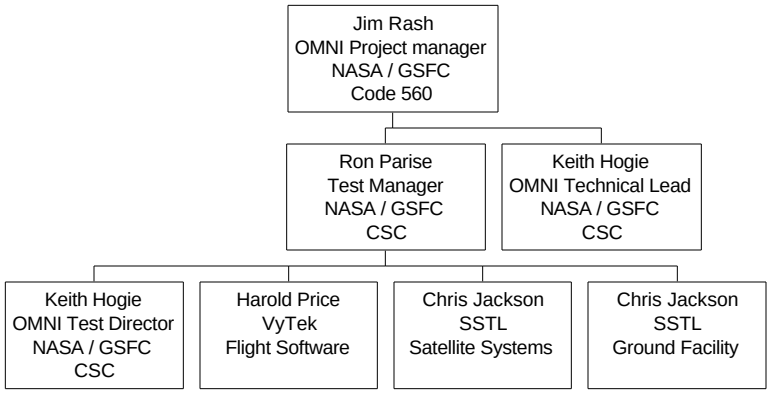

Figure 1 Organization of Test Participants

4.1 NASA/GSFC

4.1.1 Planning

The OMNI project will be responsible for developing this test plan through an interactive review, revise-and-consent process with Surrey Satellite Technology Limited (SSTL) and VyTek. The OMNI project will have sole responsibility for the establishment of the test objectives and success criteria.

The OMNI project will develop a test procedure in sufficient detail to allow a review of the test process prior to execution by all test participants prior to the test.

The test procedure will call out in a time sequence the execution steps required and the responsible personnel or organization performing the activity. Because the test staff is distributed, the procedure will clearly identify checkpoints of coordinated activities.

The test procedure will specify and provide data entry areas for recording time and status of each test activity. Where data is logged or recorded automatically by computer equipment, the procedure will specify the steps to identify the time data logging started and stopped and how the data is stored and referenced.

The test procedure will specify the test configuration. Deviations from the test configuration will be annotated in the as-run copy of the test procedure.

Deviations in the activity time line will be noted in the as-run copy of the test procedure.

4.1.2 Network Security

These tests will employ standard IP access controls available in the routers. This level of security is deemed adequate since these tests are being conducted on an aperiodic basis and do not involve spacecraft command and control systems. Future tests will investigate the use of high security techniques such as virtual private networks (VPN) and secure socket layer (SSL).

4.1.3 Data Analysis

The OMNI project will be responsible for analysis of data from test activities.

4.1.4 Reports

The OMNI project will be responsible for reporting results from test activities.

4.1.5 Contact Information

Title	Name	Organization	Phone, (FAX)	Email address
OMNI project	Jim Rash	GSFC/588	(301)286-5246	james.rash@gsfc.nasa.gov
Test Manager	Ron Parise	CSC	(301)286-3896	ron.parise@gsfc.nasa.gov
Test Director	Keith Hogie	CSC	(301)794-2999	Keith.hogie@gsfc.nasa.gov

Table 1 Contact Information

4.2 Surrey Satellite Technology Ltd.

4.2.1 UoSAT-12 Capabilities

This test plan is based on assumed capabilities and performance characteristics of the UoSAT-12 Satellite and flight software. All of the flight software capabilities will be provided by VyTek under contract to NASA/GSFC with the support of the University.

4.2.1.1 Communications Link Assumptions

1) Support for Full Duplex Communications
2) 9.6 Kbps uplink and 38.4 Kbps downlink
3) HDLC frame formatting for uplink and downlink
4) IP address assigned to spacecraft processor supporting OMNI tests.

4.2.2 Satellite Operations and Scheduling

SSTL will be responsible for providing satellite test time using the UoSAT-12 spacecraft. The test time will be scheduled such that test opportunities coincide with real-time contacts over a UoSAT ground terminal.

Prior to the OMNI tests, SSTL will provide staffing, resources, and satellite time in order to configure the satellite for the OMNI test.

The project will provide SSTL with a complete list of link activities for review prior to the test if requested.

4.2.3 Ground Terminal Facilities

SSTL will provide time and facility resources of a UoSAT ground terminal. The facility will support an IP-based network connection to the OMNI project lab at NASA/GSFC. The ground terminal will be configured to allow connection between the OMNI lab and the NASA-supplied IP router.

The ground terminal will support a connection between the project-supplied IP router and the space link communications equipment. The interface between the router and link equipment will be HDLC formatted frames. The link and interfaces will be full duplex.

Prior to the OMNI tests, SSTL will provide staffing, resources, and ground terminal time in order to configure the satellite for the OMNI test.

4.2.4 Ground Test Support

SSTL will provide the project with time and resources as agreed to in the schedule in order to integrate and test the network to space link equipment interfaces and functions prior to live test with UoSAT-12.

4.2.5 Contact Information

Chris Jackson
Phone – 011 44 1483 259141
E-mail – c.jackson@surrey.ac.uk

4.3 VyTek, LLC

4.3.1 Flight Software

VyTek will develop and provide all flight software required in the performance of this test.

4.3.1.1 Spacecraft Operating System (SCOS) Compatible IP Stack

1) Spacecraft processor assigned IP address
2) IP stack supports ICMP (Ping support), UDP, and TCP protocols

4.3.2 Flight Software Applications

1) FTP server
2) NTP server
3) UDP packet server to receive and store uplinked packets to a file.

4.3.3 Ground Test Support

VyTek will provide consultation and troubleshooting support to NASA and SSTL during ground testing with the SSTL spacecraft simulator.

4.3.4 Contact Information

Harold Price
Phone – (724) 942-1085

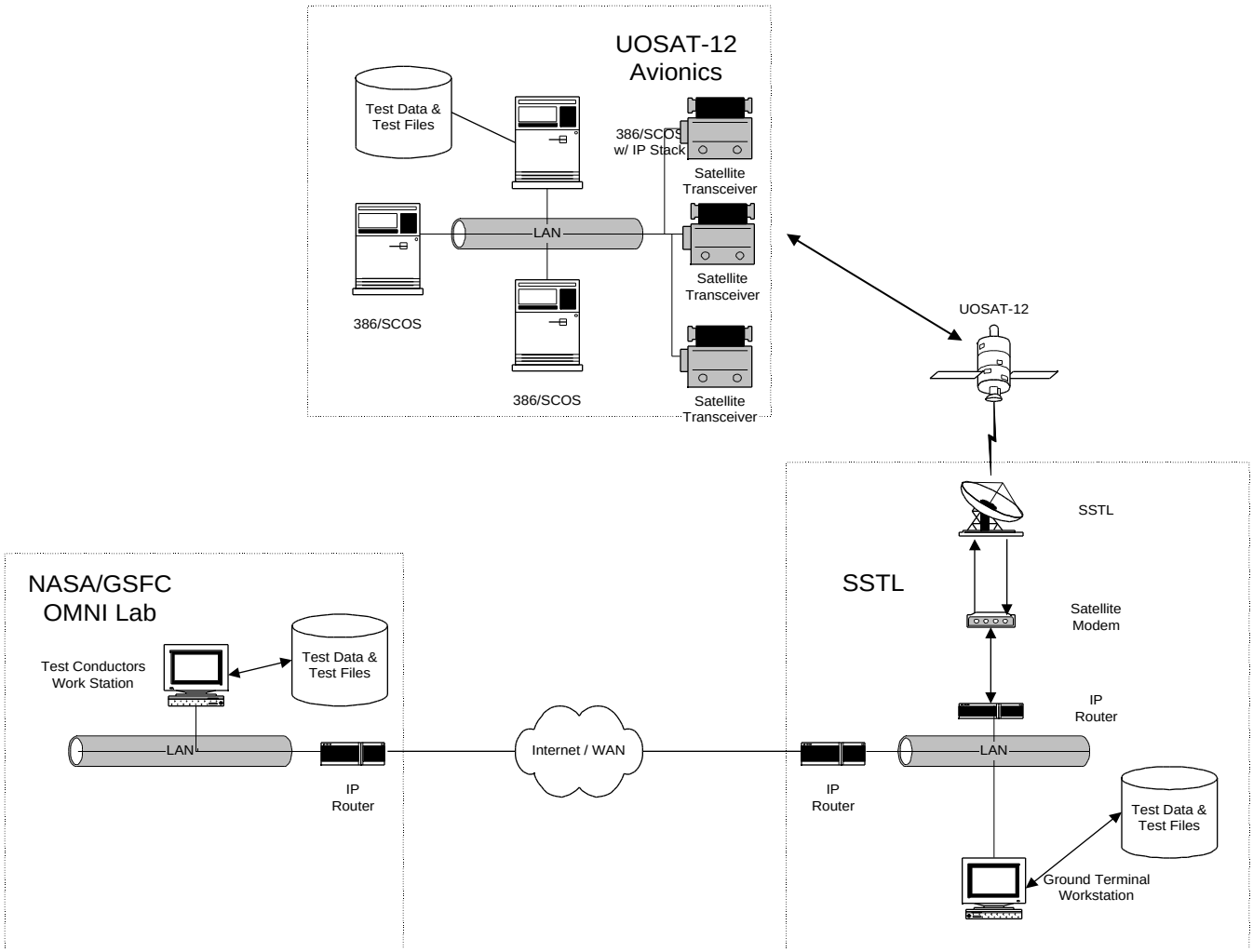

Figure 2 Basic Flight Test Configuration

5 Test Execution Phases

The testing described in this plan will be performed in four phases over a period of time. Each phase is described below.

5.1 Test Phase 0 - Test Preparations

5.1.1 Bench Test

1. The SCOS IP stack and all other flight software will be tested on the VyTek development system. All functions required by the UOSAT-12 IP test procedures developed by GSFC will be verified on the development system prior to transfer to SSTL.

2. After transfer of each flight software component to SSTL it will be tested on the UoSAT-12 engineering model computer. All functions required by the UOSAT-12 IP test procedures developed by GSFC will be verified on the engineering model flight system prior to being uploaded to the spacecraft.

5.1.2 Baseline Tests

The GSFC developed test procedure will be exercised in a simulated environment. The test environment will simulate the UoSAT-12 delay and bandwidth constraints. The purpose of this test is to verify that the test procedure will perform as expected in the UoSAT-12 environment.

5.2 Test Phase 1 – Network Connectivity and Characterization

The purpose of this test is to demonstrate seamless connectivity between an orbiting spacecraft and an arbitrary node on an existing IP network. This will be accomplished with the assistance of SSTL's UoSAT-12 spacecraft and ground station. A router within the ground terminal will handle IP routing requests to and from the space link hardware. For test purposes, the Mission Operations Center (MOC) will be the OMNI lab at NASA/GSFC in Greenbelt MD. The public Internet will be used to provide connectivity between Surrey and GSFC. Packets uplinked to UoSAT-12 will be routed by standard IP protocols. Packets from UoSAT-12 will be routed to the OMNI lab via standard IP protocols. No CCSDS or other custom link layer protocols will be used.

The phase 1 tests will utilize ping and traceroute functions to provide data for post-test analysis. The test objectives include the following:

a. Demonstrate the ability to establish a two way IP link to an orbiting spacecraft.
b. Assess the reliability of this link in an environment with no FEC.

5.2.1 Pre-test Requirements

The following hardware/software configurations must occur prior to the first test pass:

a. An OMNI workstation must be moved from the current internal subnet to the open CNE network.
b. A GSFC supplied IP router must be installed at the Surrey ground station between the Surrey LAN and the UoSAT-12 RF system.
c. The router's Ethernet port must be configured with an IP address/netmask/gateway supplied by the Surrey network administrator.
d. Verify access has been established through the Surrey firewall to the groundstation router.
e. Verify the access control list and IP address validation is in place in the groundstation router.
f. The router must be configured to provide proxy ARP service for the UoSAT-12 IP address.
g. The VyTek supplied IP protocol stack must be uplinked to UoSAT-12 and configured with an IP address/netmask/gateway supplied by the Surrey LAN administrator.

5.2.2 Data Collection Requirements

The following data will be required in order to achieve the test objectives:

a. Baseline network delay statistics between GSFC and the GSFC supplied router located at Surrey over a 24hr period.
b. Network delay measurements to the router beginning 15 min prior to and continuing until 15 min following each ground station pass.
c. Log of ping/traceroute results from GSFC directly to UoSAT-12 beginning 5 min prior to the predicted AOS and continuing until 5 min after the predicted LOS.
d. Log of ping results initiated from the GSFC supplied router at Surrey directly to the UoSAT-12 spacecraft.
e. All ping tests should be performed with a fixed packet size of 100 bytes.

5.2.3 Test Procedure

The detailed step-by-step procedure will be published in a separate document entitled "The UoSAT-12 Phase-1 IP Test Procedure."

5.3 Test Phase 2 – Basic Spacecraft Operations with IP Applications

The phase 2 test is designed to demonstrate the following spacecraft operational scenarios:

a. Reliable file delivery from an orbiting spacecraft directly to an arbitrary IP network node using the File Transfer Protocol (FTP) application. These files could contain science data, engineering data, or other ancillary spacecraft data.
b. Reliable file delivery from an arbitrary IP network node to an orbiting spacecraft using the File Transfer Protocol (FTP) application. These files could contain spacecraft or instrument commands, collaborative science data from other sensors, or new applications programs.
c. Spacecraft clock synchronization with a ground-based time standard using the Network Time Protocol (NTP) application.
d. Blind commanding using User Datagram Protocol (UDP) uplink packets containing ground station timestamps as simulated commands in the absence of a downlink.

5.3.1 Pre-test Conditions

a. Phase 1 of this test is complete.
b. The VyTek supplied FTP server and NTP application are installed on the UoSAT-12 spacecraft.
c. The GSFC router is configured to engage in NTP negotiations.
d. The GSFC router has been synchronized to an accurate time source.
e. A computer is available at Surrey to provide local FTP access to UoSAT-12 and a source of UDP packets for the blind commanding test.

5.3.2 Data Collection Requirements

The following data will be required in order to achieve the test objectives:

a. Verify proper operation of the FTP process in both uplink and downlink modes. This will be accomplished by transferring a 32KB file up to the spacecraft followed by a downlink transfer of the same file from the spacecraft.
b. Measured data throughput rates for files of approximately 125KB in size transferred from the spacecraft to an arbitrary network node in a single FTP session. The same file will be repeatedly transferred over the entire test pass.
c. Measured data throughput rates for files of approximately 32KB in size transferred from an arbitrary network node to the spacecraft in a single FTP session. The same file will be repeatedly transferred over the entire test pass.
d. Measured data throughput volume from AOS to LOS utilizing a file of approximately 5MB in size transferred from the spacecraft to an arbitrary network node in a single FTP session. The transfer will begin as soon as possible after AOS and will continue until LOS.
e. Measured data throughput volume from AOS to LOS utilizing a file of approximately 2MB in size transferred from an arbitrary network node to the spacecraft in a single FTP session. The transfer will begin as soon as possible after AOS and will continue until LOS.
f. Measured data throughput rates for multiple simultaneous FTP sessions.
g. NTP log from the router documenting the time synchronization negotiations that transpired between the router and UOSAT-12.
h. The UoSAT-12 on-board file containing the log of received UDP packets during the blind commanding test

5.3.3 Test Procedure

The detailed step by step procedure will be published in a separate document entitled “The UoSAT-12 Phase-2 IP Test Procedure.”